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Specialised Image Capture Systems for a DIET Breast Cancer Screening System

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Introduction

- **Breast cancer** has second highest mortality rate of all cancers for women worldwide. In New Zealand it is number one.

- **Mammography** is the standard for breast cancer screening
  - discomfort to patients and health risk (exposure to radiation)
  - interpretation of images is subjective → misdiagnosis, false positives

- **Digital Image-based Elasto-Tomography (DIET)** is an emerging low cost technology for non-invasive breast cancer screening
  - digital imaging of actuated breast to determine tissue motion
  - 3D internal tissue stiffness reconstruction (finite element method)
  - Regions of high stiffness suggest cancer

- **Requires up to 100 Hz image capture** (5-10 cameras ideally)
  - Problem: Cameras too large and expensive (~ $15-20k US each, high resolution)
  - Solution: “Off the shelf” CMOS imaging sensors combined with Stroboscope

DIET system overview

- The DIET system is broken down into 4 fundamental steps:

(1) Actuation → (2) Image Capture → (3) Motion Tracking and measurement → (4) Tissue stiffness reconstruction

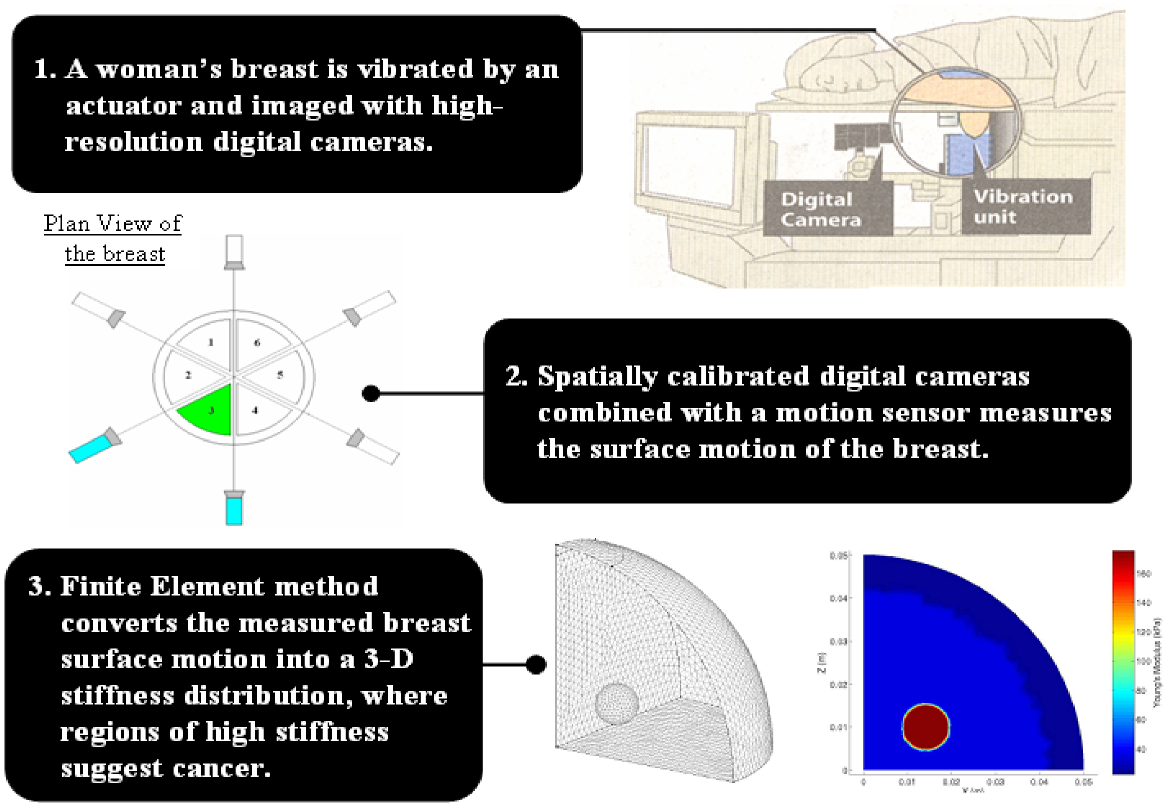


Image capture

- Image capture for DIET system → 50-100 Hz
- This research implements stroboscope with Kodak's KAC-9648 color imaging (resolution of 1280x1024)
- Other high speed cameras are either expensive, bulky or have reduced resolution
- CMOS Sensors allow dense array of cameras placed about the breast

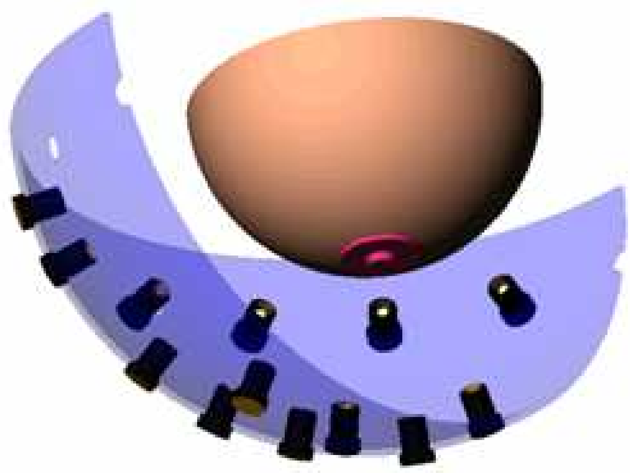
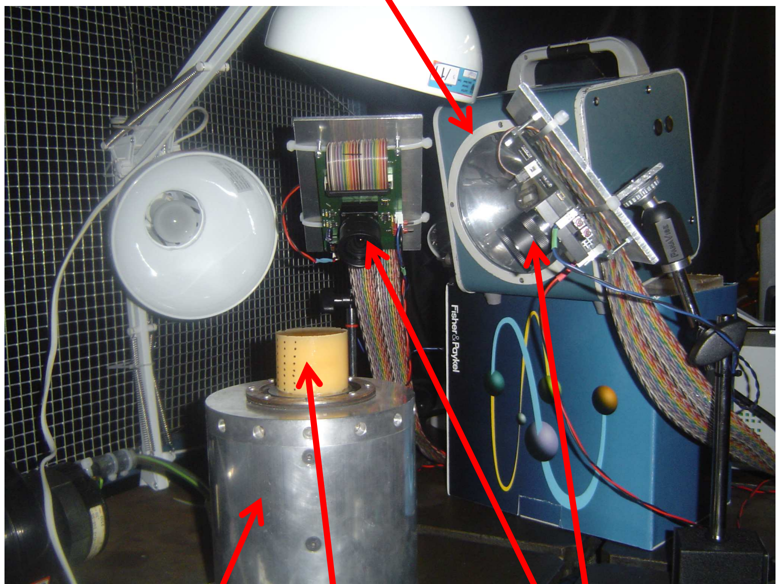


Image capture apparatus and computer setup



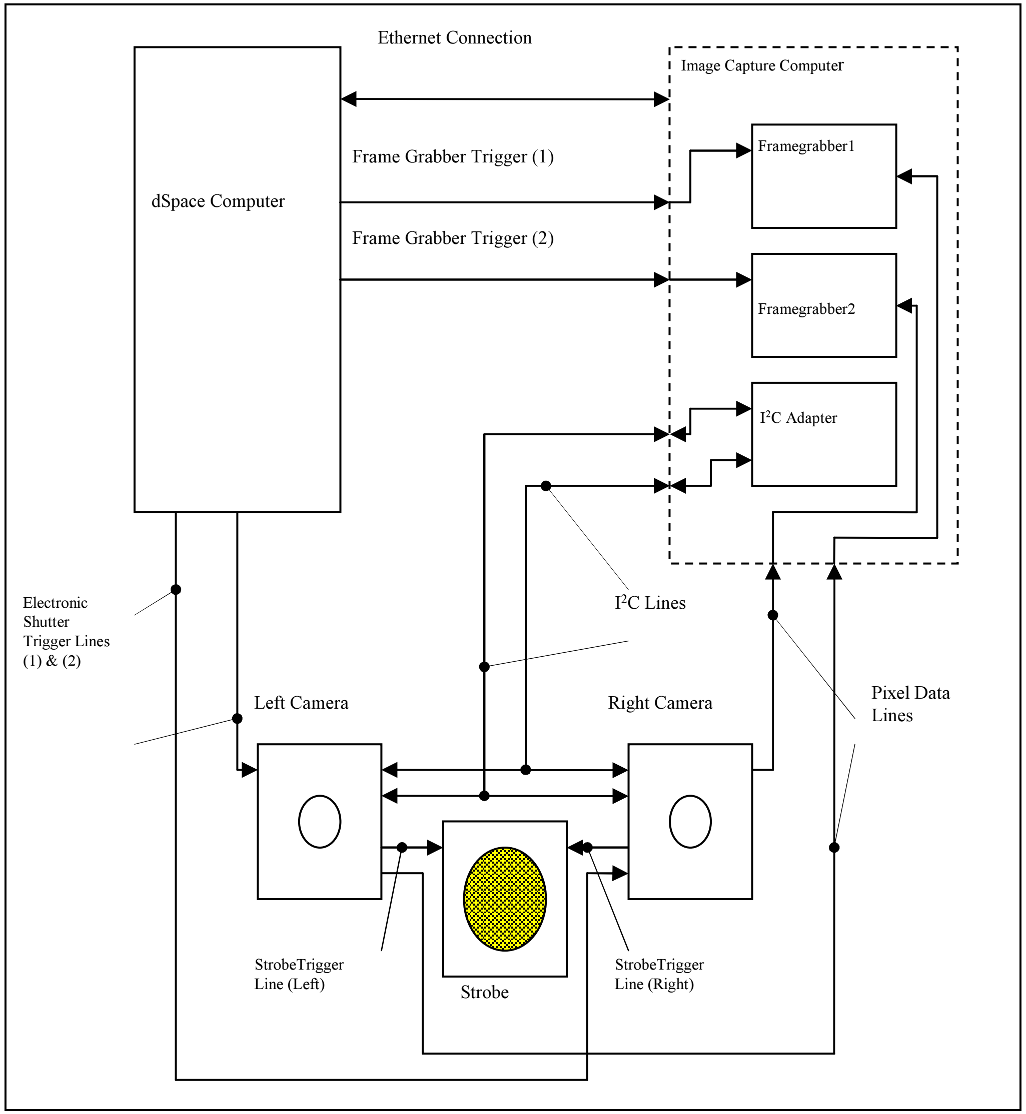
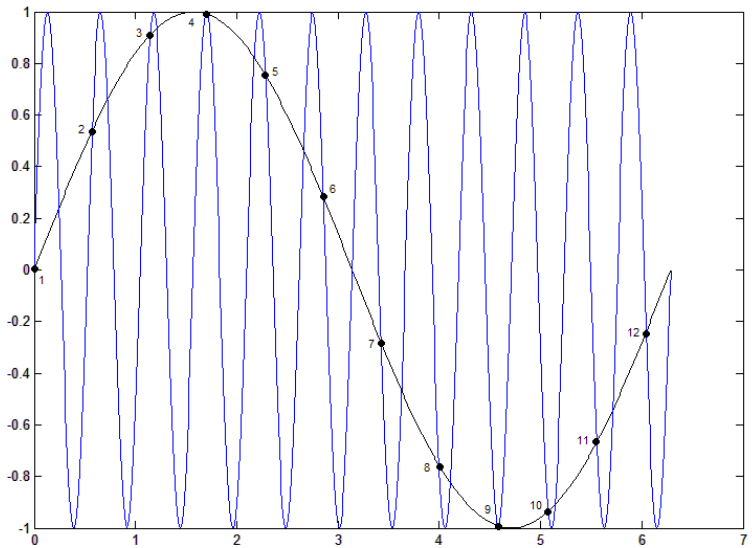


Image capture - overview

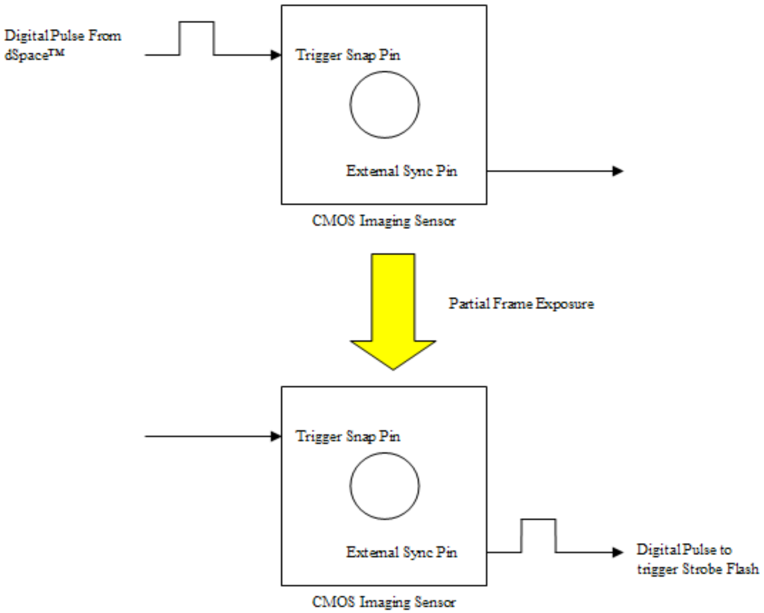
- The frame rate of each CMOS camera at 1280x1024 is approximately 18fps
- To overcome this insufficient frame rate the breast is strobed at specific points in its motion



- In practice time between captured images 1-10 seconds ➔ 100-1000 cycles between images

The cameras

- Two configurations for cameras, implemented using I^2C bus:
  (1) Initialization for camera → stream image data continuously to frame grabbers (to adjust colour gains, focus, camera position, aperture size)
  (2) Allows camera to trigger strobe itself

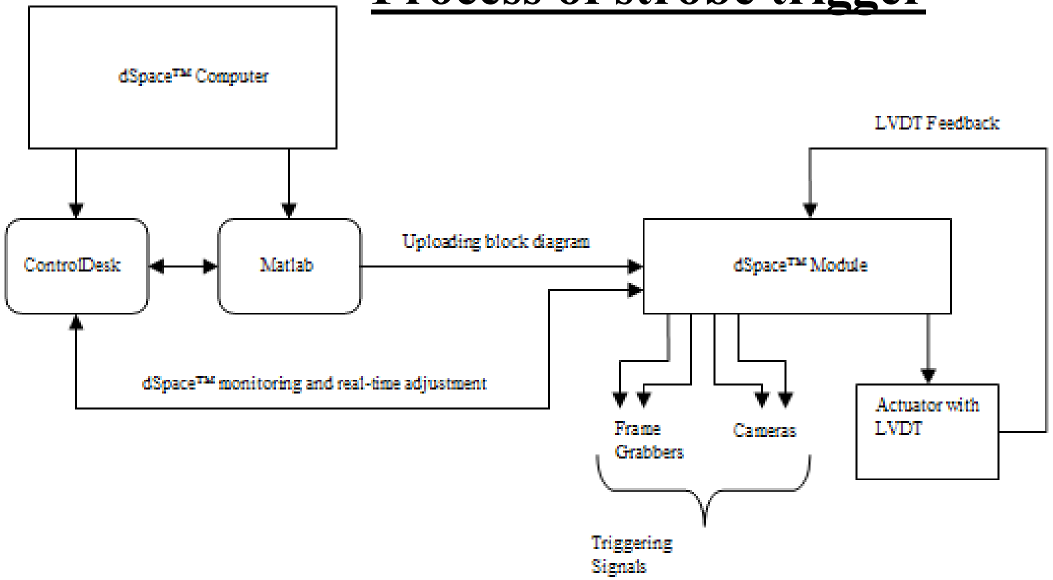


- First pin receives pulse and starts frame exposure
- Second pin supplies pulse to activate strobe

Actuator and Trigger Control

- dSpace™ control system drives image capture process (generates and synchronizes all signals)

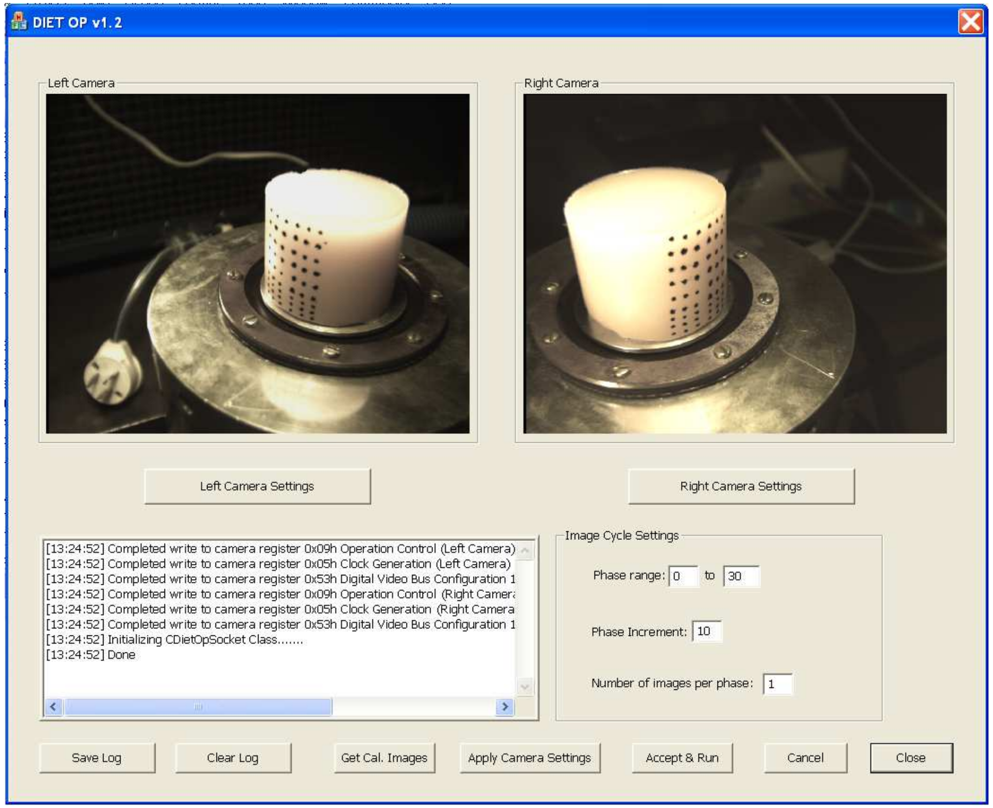
Process of strobe trigger



- dSpace™ drives trigger signals and actuator using loaded Simulink™ diagram
- ControlDesk™ software allows real-time adjustment of settings on dSpace™ module
- Python™ is used to automate ControlDesk™

Image capture software – user interface

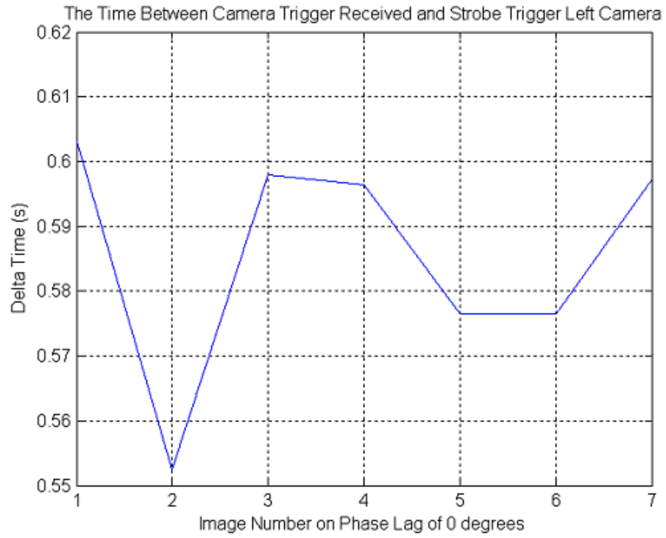
- Features of the Image Capture Application



- Can look at images and make real time adjustments (camera position, colour, …)

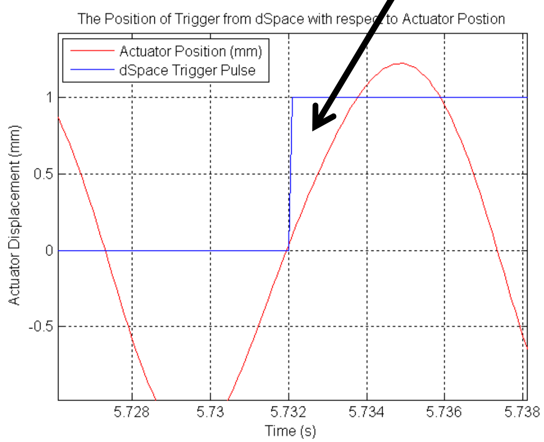
Preliminary results and problems

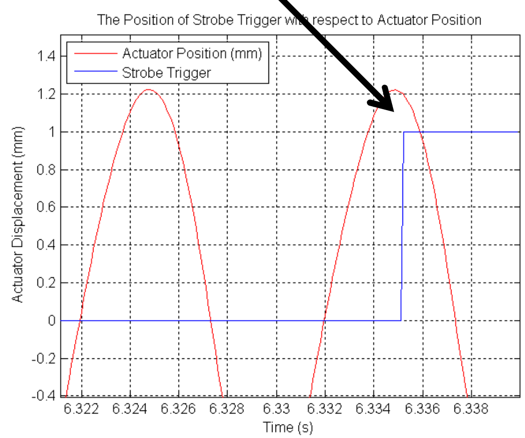
- Time period between receiving trigger from dSpace™ and camera triggering strobe is inconsistent and unpredictable
- dSpace™ triggering is consistent
- Camera is consistent at a frequency of 10Hz and not 100Hz



Signal sent from dSpace™

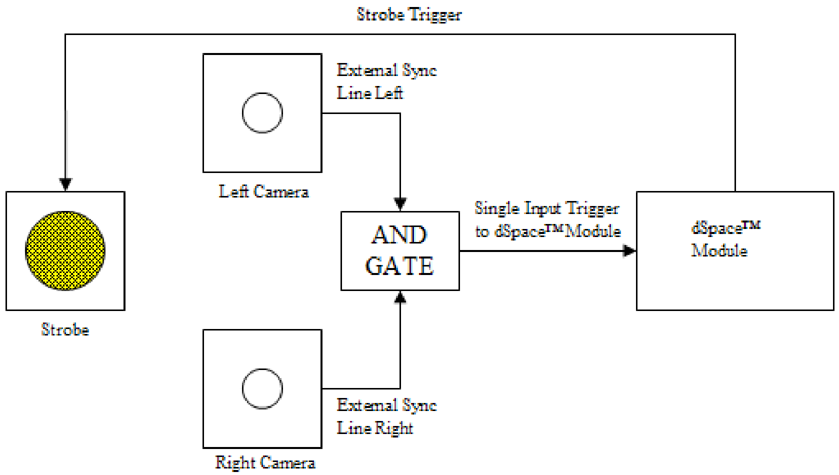
Camera takes picture (wrong point in cycle)



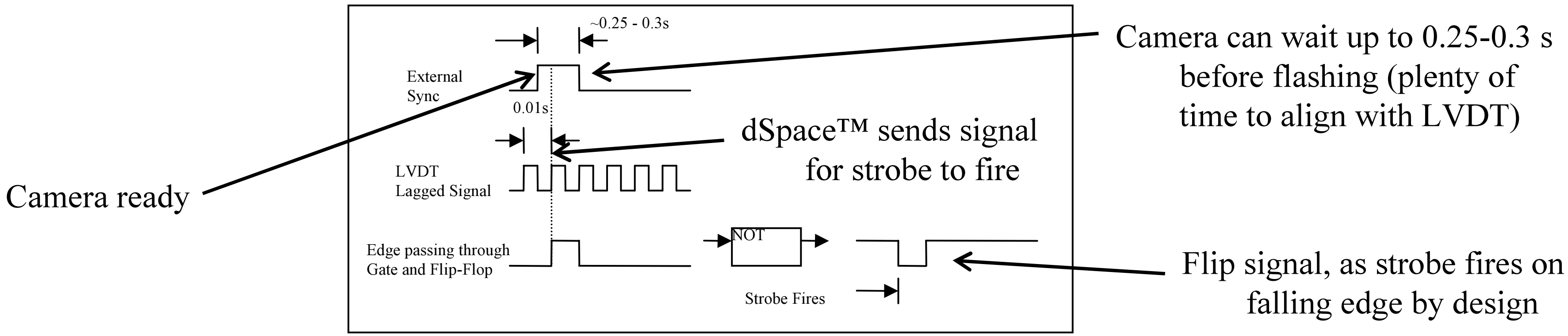


Correcting the timing

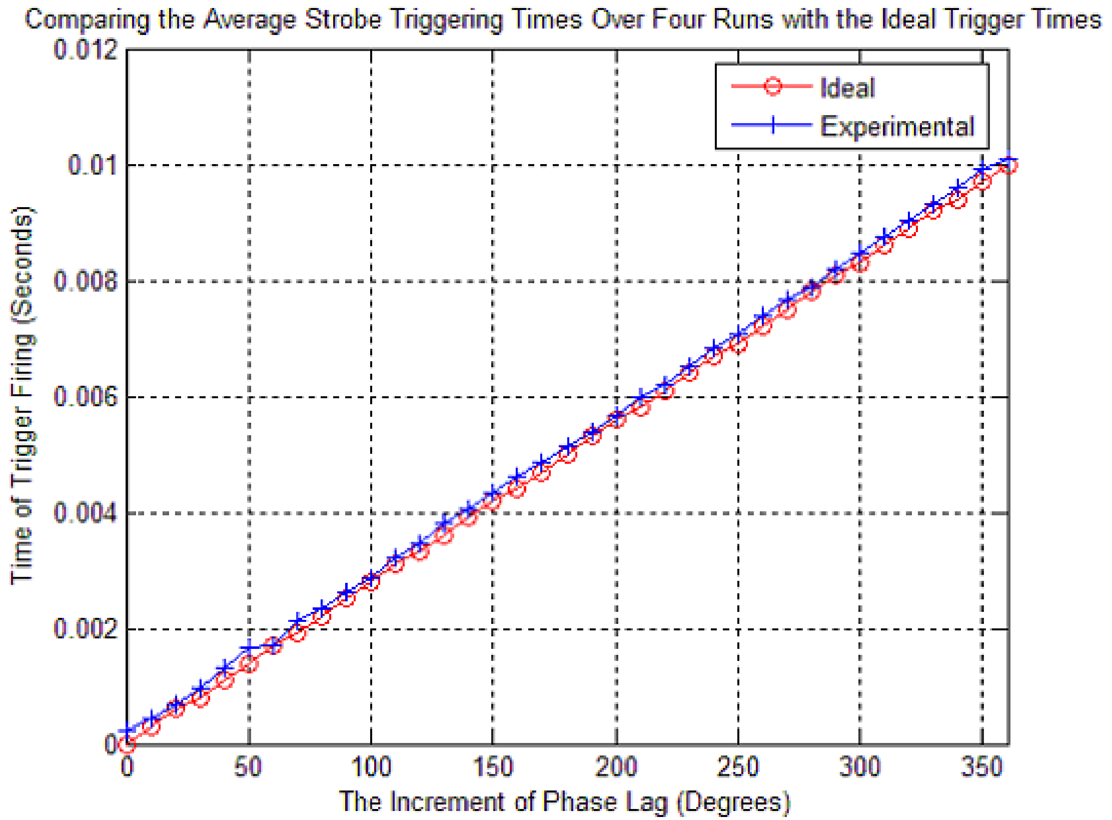
- The timing issues were solved by implementing an 'AND' gate and a feedback signal to dSpace™



- When left AND right cameras are ready for strobe, dSpace™ waits until the signal aligns with actuator, then it lets the strobe flash



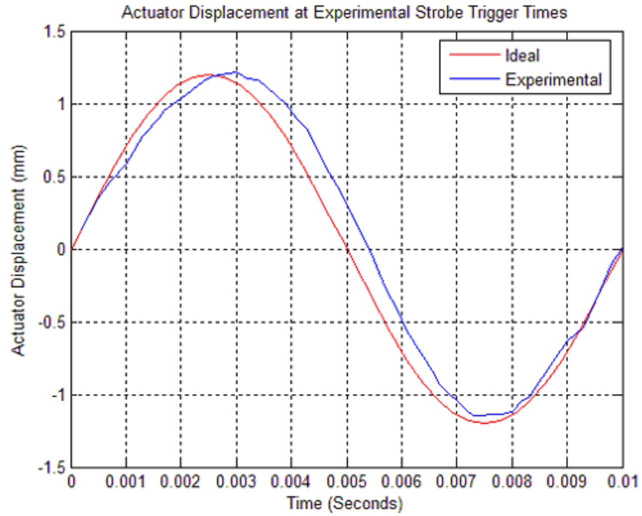
Results - timing



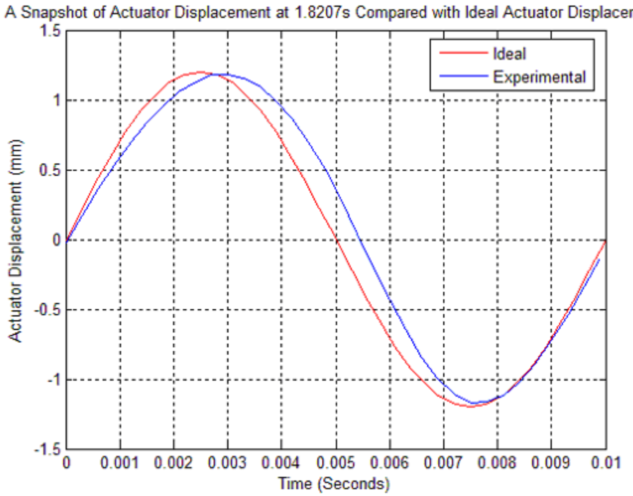
- Illustrates the accuracy in timing of the system
- Mean absolute error ~1.4% → time difference of 0.0002 seconds

Results – Actuator displacement vs ideal

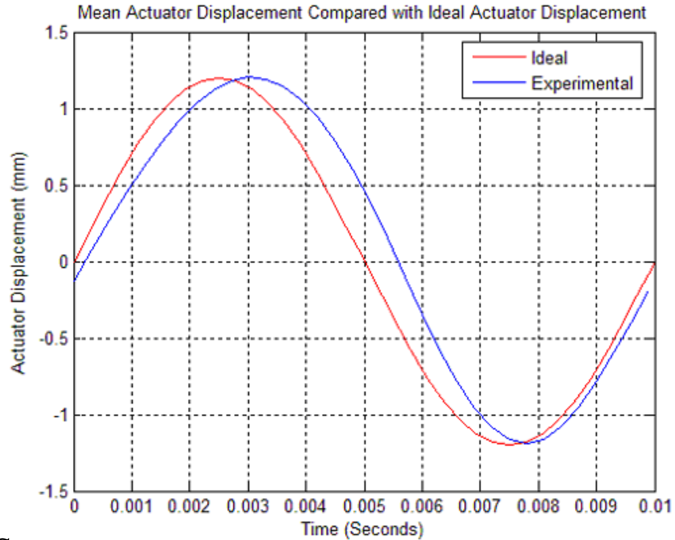
actuator displacements (10 degrees of phase) plotted as a waveform (total time=~6 minutes)



snap shot of actuators motion at t=1.82 s



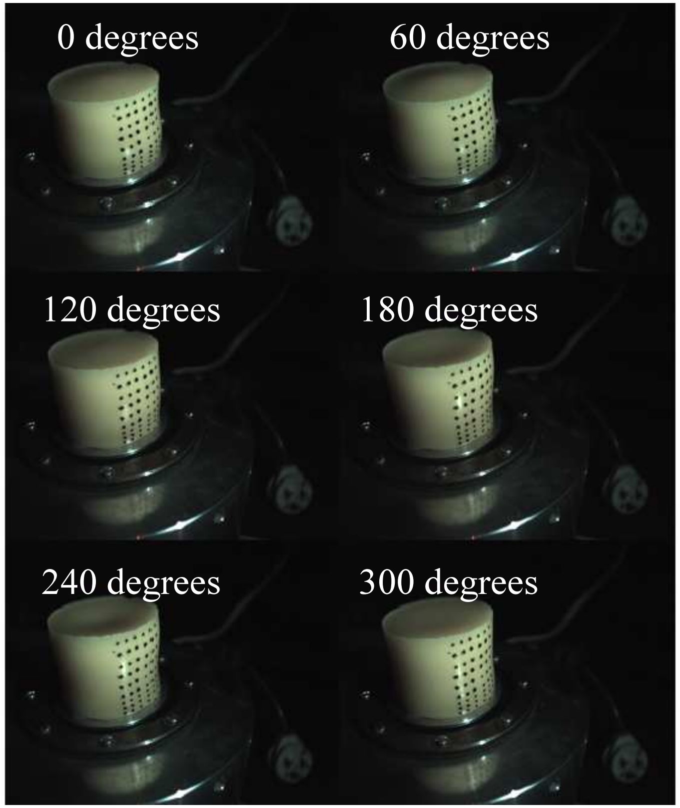
average of 20,000 waveforms (200 seconds)



- Results consistent → errors are physical limitations of current actuator (frequency varies from 95-100 Hz)

Experimental results

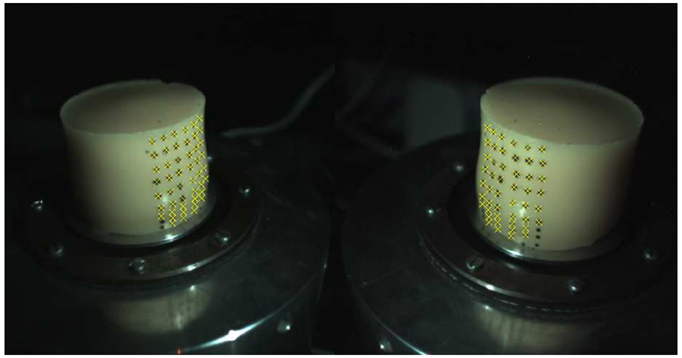
- Silicon phantom 50mm diameter, 40mm height
- Actuation frequency = 100Hz,
- Amplitude =1.2 mm

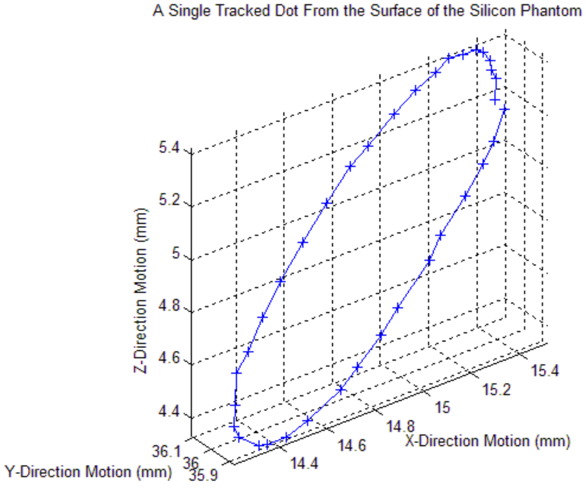


- Six images shown (60 degrees)
- 54 black dots
- 36 images = 10 degrees phase lag

3D motion tracking

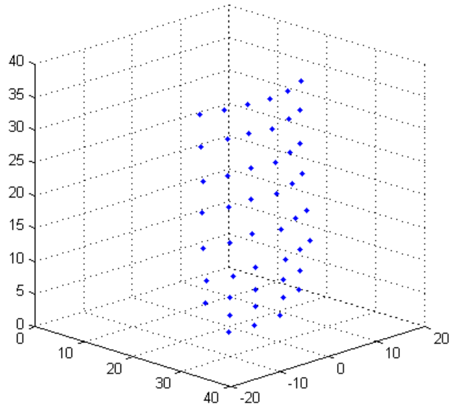
point detection

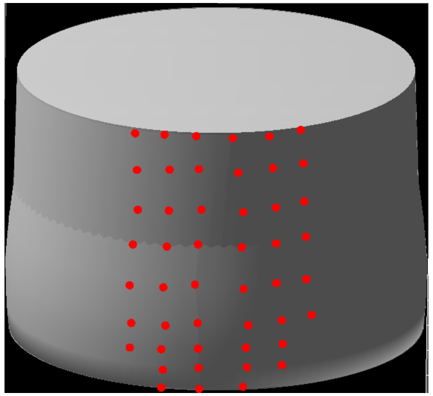




- Therefore captured images allowed successful tracking of the dots applied to the surface of the phantom

surface reconstruction (snap shot during actuator cycle)





Virtual silicon phantom constructed by symmetry – agrees with visual images throughout actuation (further validation)

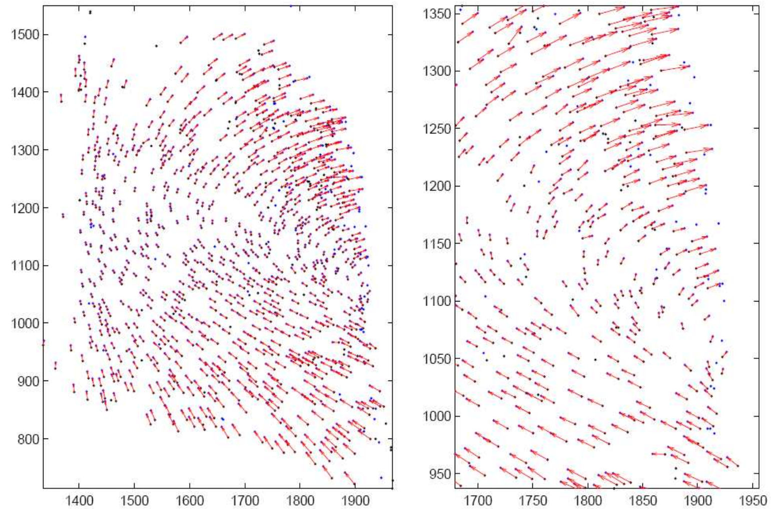
Further results

Colours and points successfully detected

- ~750 coloured fiducial marks
- 100 red, 300 blue, 350 green
- Frequency=50Hz, 1mm peak to peak
- 20 images (18 degrees of phase)

- 90% of fiducial marks tracked successfully by point tracking method (see paper)
- Based on calibration accuracy, points are tracked within 1-2% of the magnitude of the silicon response (<0.1 mm)

Example of points tracked



(a) whole set **(b) Subset (zoomed in)**

Conclusions

- **"Off the shelf" CMOS sensors + strobe = low cost DIET imaging system**

- **Image capture system successfully tested from 50-100 Hz**
  - User-specified triggering times accurately realized within 1.4%
  - Captured images allowed accurate point and colour detection
  - Accurate surface motion tracking at a high image resolution of 1280x1024

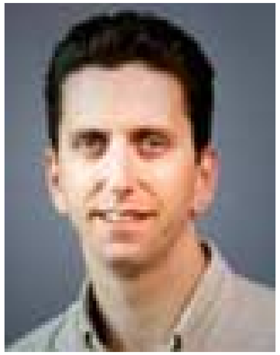
- **Total capture time = ~6 minutes**
  - Refining of Ethernet protocols and custom design system might reduce to 20-90 seconds

- **Some limitations found for current actuator (e.g. 95-100 Hz)**

  (to date has not shown to effect DIET system)

- **Future Work:**
  - Replacement of the dSpace™ module with a self contained microcontroller
  - Implementation of an auto focus system for the camera
  - **More cameras → Realistic Breast phantoms → Clinical trials**

Acknowledgements



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Questions ???